

UTILITY PATENT APPLICATION TRANSMITTAL (Small Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
8700111-0005

Total Pages in this Submission

TO THE ASSISTANT COMMISSIONER FOR PATENTS

Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

CONTROLLER FOR OIL WELLS USING A HEATED PROBE SENSOR

and invented by:

BEVAN, STUART F.
LOWNIE, TIMOTHYIf a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:
☒ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: 08/848,929

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Application Elements

1. ☐ Filing fee as calculated and transmitted as described below
2. ☒ Specification having _____ pages and including the following:
 - a. ☒ Descriptive Title of the Invention
 - b. ☐ Cross References to Related Applications (if applicable)
 - c. ☐ Statement Regarding Federally-sponsored Research/Development (if applicable)
 - d. ☐ Reference to Microfiche Appendix (if applicable)
 - e. ☒ Background of the Invention
 - f. ☒ Brief Summary of the Invention
 - g. ☒ Brief Description of the Drawings (if drawings filed)
 - h. ☒ Detailed Description
 - i. ☒ Claim(s) as Classified Below
 - j. ☒ Abstract of the Disclosure

THIS APPLICATION IS NOT TO BE REOPENED FOR FILING OF A NEW APPLICATION.

Signature: [Handwritten Signature]

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Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
a. ☒ Formal b. ☐ Informal Number of Sheets SEVEN (7)
4. ☒ Oath or Declaration
a. ☐ Newly executed *(original or copy)* ☐ Unexecuted
b. ☒ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
c. ☒ With Power of Attorney ☐ Without Power of Attorney
d. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application,
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche
7. ☐ Genetic Sequence Submission *(if applicable, all must be included)*
a. ☐ Paper Copy
b. ☐ Computer Readable Copy
c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☒ Assignment Papers *(cover sheet & documents)*
9. ☐ 37 CFR 3.73(b) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☐ Acknowledgment postcard
14. ☐ Certificate of Mailing
☐ First Class ☐ Express Mail *(Specify Label No.):* _____

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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☒ Small Entity Statement(s) - Specify Number of Statements Submitted: Filed in parent application
Serial No.: 08/848,829
17. ☐ Additional Enclosures (please identify below):

Fee Calculation and Transmittal

CLAIMS AS FILED

| For | #Filed | #Allowed | #Extra | Rate | Fee |
|--------------------------------------------------------------------------|--------|----------|--------|-----------|--------|
| Total Claims | 14 | - 20 = | 0 | x \$11.00 | \$0.00 |
| Indep. Claims | 2 | - 3 = | 0 | x \$41.00 | \$0.00 |
| Multiple Dependent Claims (check if applicable) <input type="checkbox"/> | | | | | \$0.00 |
| BASIC FEE | | | | | 380.00 |
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Dated:

Sept. 29/99

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Oil Well Pump Controller

This is a continuation of United States Patent Application No. 08/848,829 which was filed May 5, 1997.

5 The present invention relates to a controller for pumps used in oil wells and a method for controlling a pump operation.

Background of the Invention

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10 In recovery of oil from oil wells, pumps are used to draw crude oil from the well bore to the surface well head. The crude oil extracted generally consists of a combination of oil, natural gas, grit, wax and water. The pumps generally comprise two types, namely, continuous flow or on-off pumps, and are powered by either electrical or natural gas motors. Upon emerging at the well head, the crude oil is passed via a pipe to separation tanks where the oil is removed from the mixture extracted from the well bore. The oil may also be temporarily stored in the separation tanks.

15 The maximum obtainable production rate for a well depends on the rate of migration of crude oil from its geological formation to the well bore. The well bore is unique in having both an inflow and an outflow. The inflow represents the quantity of crude oil that a local formation can deliver to the well bore, whereas the outflow (or rate capacity) represents the quantity of crude oil that can be delivered to the surface (or well head). Typically, the quantity of oil that a pump is able to extract from a well bore (or
20 rate capacity) exceeds the rate of flow of the crude oil from the local formation into the well bore. This situation is normally exacerbated with age of the well. Also, the actual flow rate of crude oil into the well bore can deviate significantly at any particular point in time from an average flow rate for that well.

25 Thus, it may be seen that if the rate capacity of a pump exceeds the rate capacity of the well, the pump is then operating below maximum efficiency. As the cost of operating the pump is relatively high, this reduced efficiency translates into a wasted cost. Furthermore, severe pump degradation may be caused by having a pump operate above the well production rate. Conversely, if the pump rate falls below the wells production rate, oil accumulates in the well bore resulting in an equilibrium established
30 between oil flowing into the well bore from the formation and causing a resultant drop in production. Furthermore, for progressive cavity type pumps or continuous flow pumps, it

is necessary to always maintain fluid in the well bore. Thus, control of the pump rate is relatively more critical in this case.

Thus, there exist the need for a method and apparatus to control pump rates in response to changing rates of oil flow. There have been many attempts in the prior art to mitigate some of these problems, and in particular, the reader is referred to the applicant's U.S. patent number 5,525,040 which describes prior art attempts.

Summary of the Invention

This invention seeks to provide an oil pump controller which may be utilized to control various types of oil pumps in differing environments.

A controller for controlling the pump unit of an oil well comprising:

- a) a sensor having a first and second probe for placement in the flow of oil from the well bore;
- b) power generation means for generating a substantially constant power;
- c) a first heater in said first probe adapted to be connected to said power generation means;
- d) temperature-sensing means at each of said first and second tips respectively for generating a signal indicative of the temperature measured at each said first and second probes;
- e) control means for receiving said signals from said temperature sensing means and determining a flow rate therefrom and generating a pump control signal in response to said flow rate, said pump control signal for continuously varying a predetermined parameter of the pump unit during operation of the pump unit.

A further aspect of the invention provides for the predetermined parameter being the pump speed.

A still further aspect of the invention provides for a processor means including

- a) means for determining a temperature difference between said first and second temperature sensing means said temperature difference being indicative of a flow rate in said well;
- b) means for generating said output signal being indicative of a pump speed;

- c) means for storing a table of flowrates versus said predetermined pump speeds;
- d) means for determining a rolling average of said flowrates;
- e) means for comparing said current rolling flow average to a stored flowrate and either incrementing said pump speed if said stored flowrate exceeds said average, or decrementing said pump speed if said flowrate is less than said average;
- f) means for updating said table.

5 A further aspect of the invention provides for the temperature-sensing means to be
10 a linear RTD.

Brief Description of the Drawings

A better understanding of the invention will be obtained by reference to the detailed description below in conjunction with the following drawings in which:

- 15 Figure 1 is a block diagram of a controller according to the present invention;
Figure 2 is a cross-sectional view of a probe according to the present invention;
Figure 3 is a schematic diagram of the controller unit shown in Figure 1;
Figure 4 is a diagram of an RTD response curve;
Figure 5 is detailed circuit diagram of the controller unit of figure 3;
20 Figure 6(a) is a flow chart of a variable speed control algorithm;
Figure 6(b) is a detailed flow chart of the set-speed step of Figure 6(a); and
Figure 7 is a flow chart of an on-off speed control algorithm.

Detailed Description of Preferred Embodiments

- 25 Referring to figure 1, a block diagram of a pump controller is shown generally by numeral 10. A variable speed pumping unit 12 extracts crude oil from a well bore 14, which is then pumped via a conduit 16 to a holding tank 18, or the like. The pump control system includes a sensor 20 which is placed in the path of the oil flow in the conduit 16, in a manner to be described below. The sensor 20 provides an electrical
30 signal indicative of flow via a cable 22 to a main control unit 24. The control unit 24 provides a control signal 26 to control the variable speed pump unit 12. The control

signal 26 maintains the pump speed at an optimal level in order to ensure efficient extraction of crude oil from the well bore 14. An external computer 28 may be connected to the controller unit 24 in order to download or control parameters of the controller. Furthermore, the computer 28 includes a graphical display system for displaying
5 information on the controller performance. Each of these elements will be discussed in detail below.

Referring to figure 2, a cross-section of the sensor 20 in figure 1, is shown. The sensor 20 is a passive device in that it must be powered from the controller 24. The sensor includes a cylindrical body section 30 and a lower threaded section 32 for
10 installing in a bore of a T-pipe section 15 in the conduit 16. Generally, the sensor is installed relatively close to the well head. A pair of probes 34 and 36 project from one end of the body 30 so that when the sensor is inserted into the conduit 16, oil can flow over each of the probes uniformly. The actual orientation of the probes within the conduit is not critical, however, the probes should project generally perpendicularly to the
15 direction of flow in the conduit. The probes 34 and 36 are each comprised of a hollow polished stainless steel tube and each contain a heating element 38,42 and a temperature sensing element 40,44, respectively. A heating current derived from the controller 24 is provided to the heating element 38 and 42 via a suitable electrical conductor 46 and temperature measurement signals are returned from the temperature sensing elements to
20 the controller via a pair of conductors 48. The conductor 46 and 48 are attached to a connector 49 which may be attached to cable 22.

The sensor operates on a thermal dispersion principle based on Newton's law of cooling. One of the probes is selected and its heating element is supplied with a constant energy, which radiates out as heat. We generally refer to this probe as the energized
25 probe. Its counterpart probe or unheated probe is generally called the ambient probe. Both the probes provide a temperature signal from their respective temperature sensing elements. Thus, it may be shown that the heat input rate into a medium may be expressed by the equation $Q = h\Delta t$, where h is the convection heat transfer co-efficient and Δt is the temperature difference between the heat source and the medium. In this case, Δt is the
30 temperature difference between the heated and ambient probes. The value h is a function of the flow rate of the medium. Hence, h is not constant. Thus it may be seen that the

temperature differential between the probes is inversely proportional to the flow rate of the medium for a given heat input rate Q.

It may be more accurately stated that the velocity of the fluid is a function of the inverse of the square of the difference in temperatures between the two probes. By heating one of the probe tips at a constant rate, the difference in temperature between the probe tips provides a relative temperature measurement independent of the ambient temperature of the fluid.

The calculated velocity of the fluid is proportional to the square of the energy transfer into the probe. Therefore, it is important that the energy supplied to the probe is stable over a wide range of ambient conditions. Furthermore, in situations where high flow exist, most of the radiated heat is absorbed by the passing fluid and carried down stream. The temperature thus recorded at either of the energized or ambient probe is approximately the same. However, with reduced fluid movement across the probes, residual heat builds up along the tip of the energized probe thus resulting in a higher temperature measurement relative to the ambient probe. By comparing the energized probe temperature to the ambient probe temperature, the flow rate can be estimated to produce a value which is substantially independent of the temperature of the oil flowing past the probe. Additional compensation for the variation of constant fluid properties from well to well with temperature is implemented in the controller 24.

Referring now to figure 3, the controller 24 is shown in greater detail. The sensor electronics is shown schematically by block 20. The controller 24, includes a heater constant current source supply 51 which provides a constant current to the heater elements 38 and 42 located in the sensor 20. Each of the heater elements 38 and 42 are connected to a respective switch 54 and 56. These switches 54 and 56 are selectively controlled via a micro-controller 58 for selecting either one of the heater elements 38 or 42 to be heated.

As described earlier, each of the heater elements has in close proximity thereto a temperature sensing element 40 and 44. The temperature sensors in this case are platinum RTDs (resistance-to-temperature devices). As may be seen in figure 3, each of the RTDs 40 and 44 have one of their inputs 59 connected via a switching multiplexer 60 to an RTD constant current source 66. The output of the temperature sensor resistors 40

and 44 are connected via the multiplexer 60 to the analog input of an analog-to-digital converter 64 through a buffer amplifier 65. The analog-to-digital converter 64 provides a digital input to the micro-controller 58 which is indicative of the temperature measured by a respective RTD 40 or 44. As seen in figure 4, the RTD devices are linear devices and are capable of exhibiting a linear resistance change over an approximate temperature range of -19°C to 150°C. The micro-controller 58 then processes this input data described with reference to figures 6(a), 6(b) and figure 7. A digital-to-analog converter 67 has its digital inputs driven by an output of the micro-controller 58 to produce an output analog signal indicative of a speed control signal 26 for control of the pumping unit 12 shown in figure 1.

In addition, an RS232 interface and driver support circuitry 72 is provided for communication with the micro-controller 58 by the external computer 28. Additional E² PROM 73 is provided for storage of constants and additional parameters.

Referring to figure 4, a resistance-to-temperature graph 74 illustrating the relationship between the resistance and temperature of the RTD is shown generally by numeral 80. It may be seen that the relationship is relatively linear over a large temperature range. This has the advantage in that over a period of time, the temperature of the resistor may be sampled by the analog-to-digital converter 64 and an integer interpolation routine may be used to determine values of resistance between the sampled points. Thus, it is not required that a large amount of memory be utilized in the micro-controller in order to store a lookup table, as for example, when a non-linear thermistor is used as temperature sensing element.

By providing heating elements in each of the probes of the sensor 20, allows for each of the probes to be periodically made the energized probe. In the case of oil wells with high paraffin wax content, if only one of the probes is heated, then over a long period of time, wax would tend to accumulate on the unheated probe. This would result in skewed temperature readings. However, by providing heaters in both probes and providing a means for switching between the heaters in the probes reduces wax build up on the probes. Furthermore, the lifespan of the sensor is extended by switching the heating elements between the probes since constant heating of only one of the probes results in sever degradation of the lifespan of that probe.

Figure 5 is a detailed circuit diagram of the controller 24, wherein the micro-controller is a type 68HC705.

Referring now to figures 6a and 6b, an algorithm implemented by the micro-controller 58 for controlling the output signal 26 to the pump, is indicated generally by numeral 90. The micro-controller switches the constant power source 57 to one of the heaters 30 or 42 by activating one of the switches 54 or 56. The micro-controller then obtains a first T_1 and second T_2 digitalized temperature measurement from the input signal received from the analog-to-digital converter 64 by sending a signal to the multiplexer 60 to select in sequence the temperature probe 40 or 44. The difference between these temperatures ΔT is calculated and is indicative of a flow measurement. These flow measurements or temperature differentials are combined into an average of most recent samples called a *rolling flow average*. The micro-controller samples the temperature approximately once ever second. The controller stores a sixteen element rolling window of samples. Once sixteen samples have been included in a rolling window, the newest sample replaces the older sample prior to the latest average being calculated. That is, a rolling average is calculated over a sample of sixteen elements every second with each element being discarded after 16 seconds. The process of obtaining flow measurements is continuous and proceeds in parallel with other processing by the micro-controller.

Once this flow is obtained by the micro-controller, the oil flow at the well head is controlled in accordance with the sequence of steps illustrated in figures 6(a) and 6(b). Initially, an auto reset clock 92 is set to count time down from 48 hours or any other convenient time. This clock serves to reset the parameters of the controller in order to accommodate drops in motor efficiency over time and to switch the heated probe.

The micro-controller maintains a speed table of entries having rows of measured flow rates M_i and pump speed S_i . Thus, at a step 94, this table is initialized. An initial wait time is then set at step 96. This period is initially set between 8 to 12 minutes.

It may be noted that for variable speed control applications, the digital-to-analog converter delivers 4 to 20 milliamps output signal. By convention, 4 milliamps represents the lowest speed setting S_0 of the pump, while 20 milliamps represents the

highest speed S_n setting of the pump. An increment or step in speed is generally designated as 1 milliamp representing the least step up or step down for change in speed.

In implementing the variable speed control, it is assumed that each increase in speed corresponds to some increase in the maximum potential delivery rate of the pump.

5 Thus it is the goal to operate the pump at the lowest speed with the delivery rate above the current production rate measured for the well. Thus, in order to achieve this, the speed table, as described earlier, keeps track by way of the *rolling flow average* of the maximum delivery rate obtained thus far for each selected speed of the pump.

Changes in speed occur on the basis of time intervals. The length of each interval
10 is called the settled time T_s . Its purpose is to allow changes in the pump speed and the well's production rate to be reflected in the rolling flow average. By default, the length of the settle time is 2 minutes. At the end of each interval, depending on whether the rolling average has increased, decreased or stayed the same, a corresponding change in speed is initiated. These changes in speed may be made as a single increment or as an
15 arbitrary number of increments per interval.

Thus, referring back to step 98 in figure 6, an initial speed S_i of the pump is set. The controller waits a predetermined time at step 99. A new speed is then set at step 100 according to the algorithm of figure 6(b). The table is initially built from the lowest speed S_0 upward, first, the speed is set to S_0 and an initial flow M_0 is obtained for speed
20 S_0 . The speed is then stepped up to S_1 and a corresponding flow M_1 is obtained. This is repeated for successive values of speed increments. It is assumed, however, that each step between a speed S_i and a speed S_{i+1} corresponds to a corresponding step in the maximum potential flow rate. Therefore, if upon obtaining M_{i+1} at speed S_{i+1} , it is recognized that $M_{i+1} \leq M_i$, then it is clear that the well's current production rate is below
25 what the pump can deliver at speed S_{i+1} . For example, if M_{i+1} is equal to M_i , it indicates that the well at this time is producing at a constant rate which corresponds to a speed S_i . Otherwise, if M_{i+1} is less than M_i , it indicates that during the settle interval at S_{i+1} , production from the well has decreased. In this case, S_i may represent a greater speed than is required to support the lowered production rate. Therefore, a search of the table is
30 performed beginning at S_i down to S_0 until the lowest speed having a maximum delivery rate above the current production rate is found.

It may therefore be seen that building the speed control table occurs in conjunction with varying the pump speed. When production levels or flow rates from the well increase, the table is refined while the speed is increased. Conversely, when lower flow rates are measured from the well, the table is searched for the minimum speed required to sustain that flow rate.

To illustrate how the process of building a table is performed after a drop in flow rate is detected, let S_p represent the last speed prior to detecting a drop in flow rate, and let S_i be the current speed. For example, S_p might be 12 mA and S_i might be 9 mA. As flow rate from the well increases, the production rate at speed S_i as measured by the rolling flow average will begin to approach M_i , which is the estimated maximum flow rate at S_i . At the end of an interval, if the production rate is found to be closer to M_i , then the speed is incremented up to S_{i+1} . Assuming production levels continue to improve, the speed is successively increment up to S_p . As this point, the table is continued to be built until either flow rate decreases or the maximum speed S_n is reached.

Alternatively, if at the end of the interval at speed S_i , the production rate may be greater than M_i . In this case, M_i is no longer the best estimate to the maximum flow rate at S_i . The new flow rate is then substituted for the old value of M_i . The change to M_i can also impact M_{i+1} , if the new value for M_i is also greater than M_{i+1} . Therefore, the table is rebuilt for S_{i+1} . Thus, it may be seen that changes can precipitate through entries in the table thus allowing the controller to constantly fine tune its estimates based on better information over time. This is illustrated more clearly in figure 6(b). Once the new speed S_i is set at step 100, a new settle time is set at step 102.

Besides the settled time, there are two other timing intervals involved in variable speed control. These are the initial wait and automatic reset time. The initial wait time is simply the settling time for the very first interval in building the table. As such, it only occurs once just after the instrument is reset or powered on. The initial wait is typically longer than the settled time.

The automatic reset time is not directly related to variable speed control. Instead, it is simply a background timer which upon time out at step 104 initiates an automatic reset of the controller. This causes the speed table to be rebuilt. The automatic reset serves several purposes as described earlier.

Referring now to figure 7, a process flow for controlling an on/off type pump is shown generally by numeral 170. In this case, the micro-controller 58 may send a signal to the digital-to-analog converter 67 one of two signals, namely, a value corresponding to a pump-off signal or a value corresponding to a pump-on signal. Alternatively, a relay 67 may be provided which turns the pump 12 on or off. The process is divided into four steps, namely, establish flow 172, regulate flow 174, timing-out 176 and shut-in 178. It is to be noted that each step is associated with a single control parameter which directs the process of that step. A default setting is assigned to each control parameter. However, these parameters may be easily changed via the external computer 20. The parameters associated with these steps are establish flow period, regulate flow cutoff point, timing-out period and shut-in period. Generally, these parameters are set at a default value of 15 minutes, 25%, 1 minute and 30 minutes, respectively.

The establish flow step 172 starts the pump and settles into an interval of time called the establish flow period 173. This establish flow period is indicative of a flow of the current state of the well. For example, this interval generally covers the time required for oil to make its way to the surface and past the probes. Although flow samples are obtained by the controller during this period, output signals to control the pump are not provided during the establish flow period. Once the establish flow period has expired at step 173, the process moves onto the regulate flow step 174.

In the regulate flow period 174, an ongoing flow sample is combined into a rolling average called the rolling flow average as described earlier. However in this case, a rolling flow average is compared against a regulated flow cutoff point 175. If the rolling flow average remains above the cutoff point, a process control cycle remains at this step. However, should the rolling flow average drop below the regulated flow cutoff point, this signals a pumpoff has occurred and the process moves on to the timing-out step 176.

In the time out step 176, a short period called the time out period is provided to confirm whether or not the well has actually pumped off. This avoids instances where trapped gas pockets are within the line or short segments of dry pumping have occurred. During timing out, the ongoing rolling flow average continues to be compared against the regulated flow cutoff point 177. If the rolling average moves back above the cutoff point

before timing out period expires, then the process moves back to the regulate flow step 174. Otherwise, at the end of the timing out period, the process moves to the next step which is the shut-in step 178.

5 In the shut-in step 178, the pump is stopped and the well enters an idle state allowing time for the well bore to be refilled from the surrounding formation. The length of time the well remains idle is determined by the shut in period. Once the shut in period expires, the process control begins at the establish flow step 172.

10 While the invention has been described in connection with a specific embodiment thereof and in a specific use, various modifications thereof will occur to those skilled in the art without departing from the spirit of the invention as set out in the claims.

15 The terms and expressions which have been employed in the specification are used as terms of description and not of limitations, there is no intention in the use of such terms and expressions to exclude any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention as set out in the claims.

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We Claim:

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- 30
1. A controller for controlling a pump unit of an oil well comprising:
 - a) a sensor having a first and second probe for placement in the flow of oil from the well bore;
 - b) power generation means for generating a substantially constant power;
 - c) a first heater in said first probe adapted to be connected to said power generation means;
 - d) temperature-sensing means at each of said first and second tips respectively for generating a signal indicative of the temperature measured at each said first and second probes;
 - e) control means for receiving said signals from said temperature sensing means and determining a flow rate therefrom and generating a pump control signal in response to said flow rate, said pump control signal for continuously varying a predetermined parameter of a pumping unit during operation of said pumping unit.
 2. A controller as claimed in claim 1, said predetermined parameter being said pump speed.
 3. A controller as claimed in claim 1, said first heater being a resistor.
 4. A controller as claimed in claim 3, said power generation means being a first constant current power source.
 5. A controller as claimed in claim 1, said temperature-sensing means being a resistance device having a substantially linear change in resistance in response to ambient temperature change.
 6. A controller as claimed in claim 5, said resistive device being a linear RTD.

7. A controller as claimed in claim 1, including a second heater in said second probe adapted to be connected to said power generation means.

5 8. A controller as claimed in claim 7, including switching means for selectively connecting either said first or second heater to said power generation means.

9. A controller as claimed in claim 5, including a second constant current power source adapted for connection to said resistive devices.

10

10. A controller as claimed in claim 9, said control means including an analog-to-digital converter for converting said signals generated by said resistive devices to a digital signal.

15 11. A controller as claimed in claim 1, said control means including a processor means, said processor means comprising:

a) means for storing an established flow time, shut-in time, a time-out period and a low-flow point;

20 b) means for determining a temperature difference between said first and second temperature sensing means said temperature difference being indicative of a flow rate in said well;

c) means for storing said flowrate;

25 d) means for comparing said flowrate with said low-flowpoint and for updating the timing-out period if said flowrate is grester than said low-flow point; and

e) means for generating said output signal to turn said pump unit off when said timing o-out period has expired and for turning on said pumping unit when said shut-in period has expired.

30 12. A controller as claimed in claim 11, including means for determining a rolling average of said flowrates.

13. A controller as claimed in claim 1, said control means including a processor means, said processor means comprising:

- a) means for determining a temperature difference between said first and second temperature sensing means said temperature difference being indicative of a flow rate in said well;
- b) means for generating said output signal being indicative of a pump speed;
- c) means for storing a table of flowrates versus said predetermined pump speeds;
- d) means for determining a rolling average of said flowrates;
- e) means for comparing said current rolling flow average to a stored flowrate and either incrementing said pump speed if said stored flowrate exceeds said average, or decrementing said pump speed if said flowrate is less than said average; and
- f) means for updating said table.

14. A method of controlling a pump unit of an oil well comprising the steps of:

- a) placing a sensor having a first and second probe in the flow of oil from said well bore;
- b) generating a substantially constant power by a power generation means;
- c) connecting a first heater in said first probe said power generation means;
- d) generating a signal indicative of the temperature measured at each said first and second probes by temperature sensing means at each of said first and second tips respectively;
- e) receiving said signals from said temperature sensing means at a control means;
- f) determining a flow rate; and
- g) generating a pump control signal in response to said flow rate, said pump control signal for continuously varying a predetermined parameter of a pumping unit during operation of said pumping unit.

ABSTRACT

A controller for controlling the pump unit of an oil well includes a sensor having a first and second probe for placement in the flow of oil from the well bore. Each of the probes contains a heater. A constant power source is selectively connected to one of the heaters. Each of the probes also include a linear RTD at each of their tips respectively for generating a signal indicative of the temperature measured at each of the first and second probes. A control unit receives signals from the RTD's and determines a flow rate therefrom. A pump control signal is generated in response to the flow rate, wherein pump control signal continuously varies a predetermined parameter of a pumping unit during operation of the pumping unit.

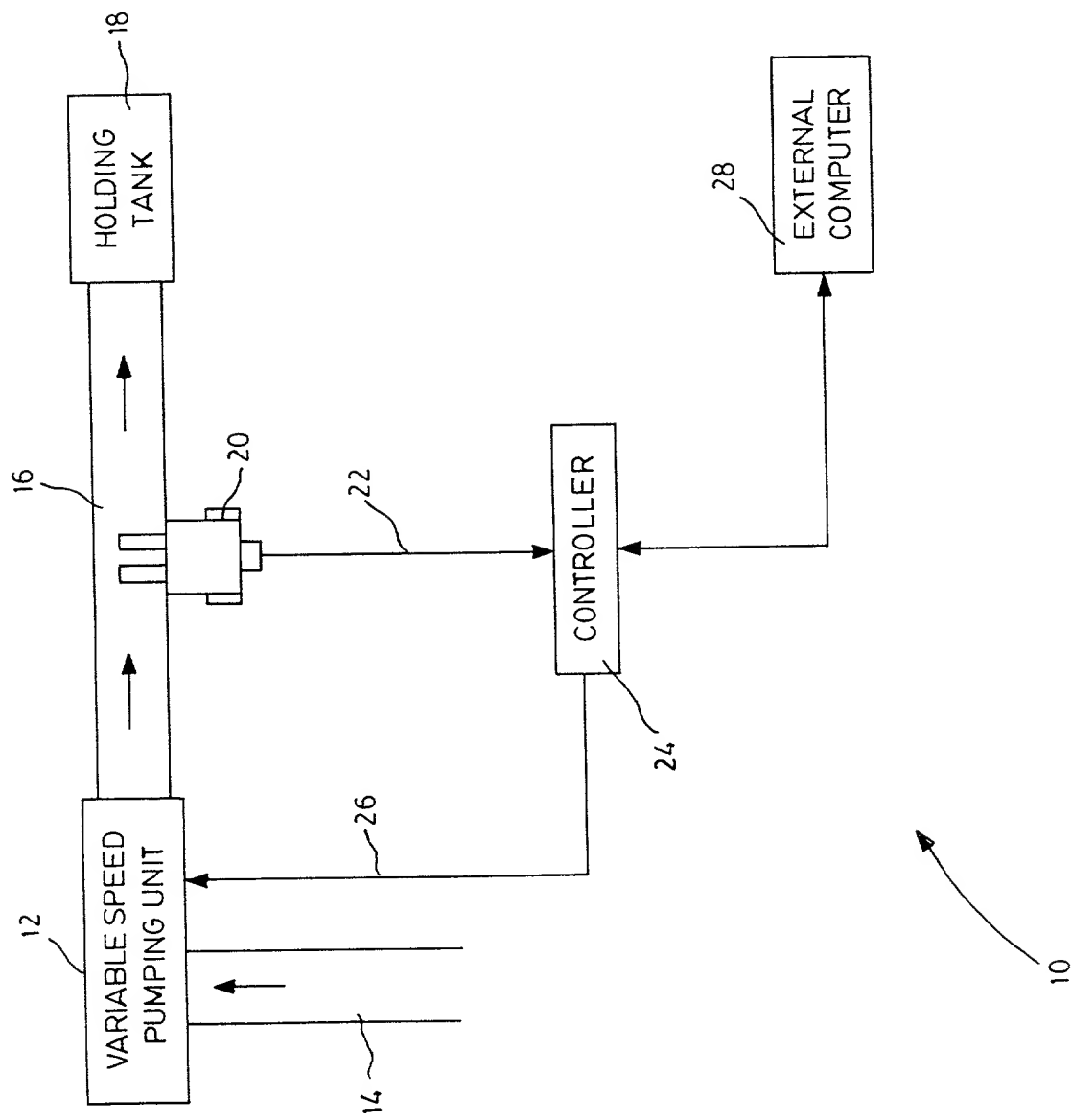


FIG. 1

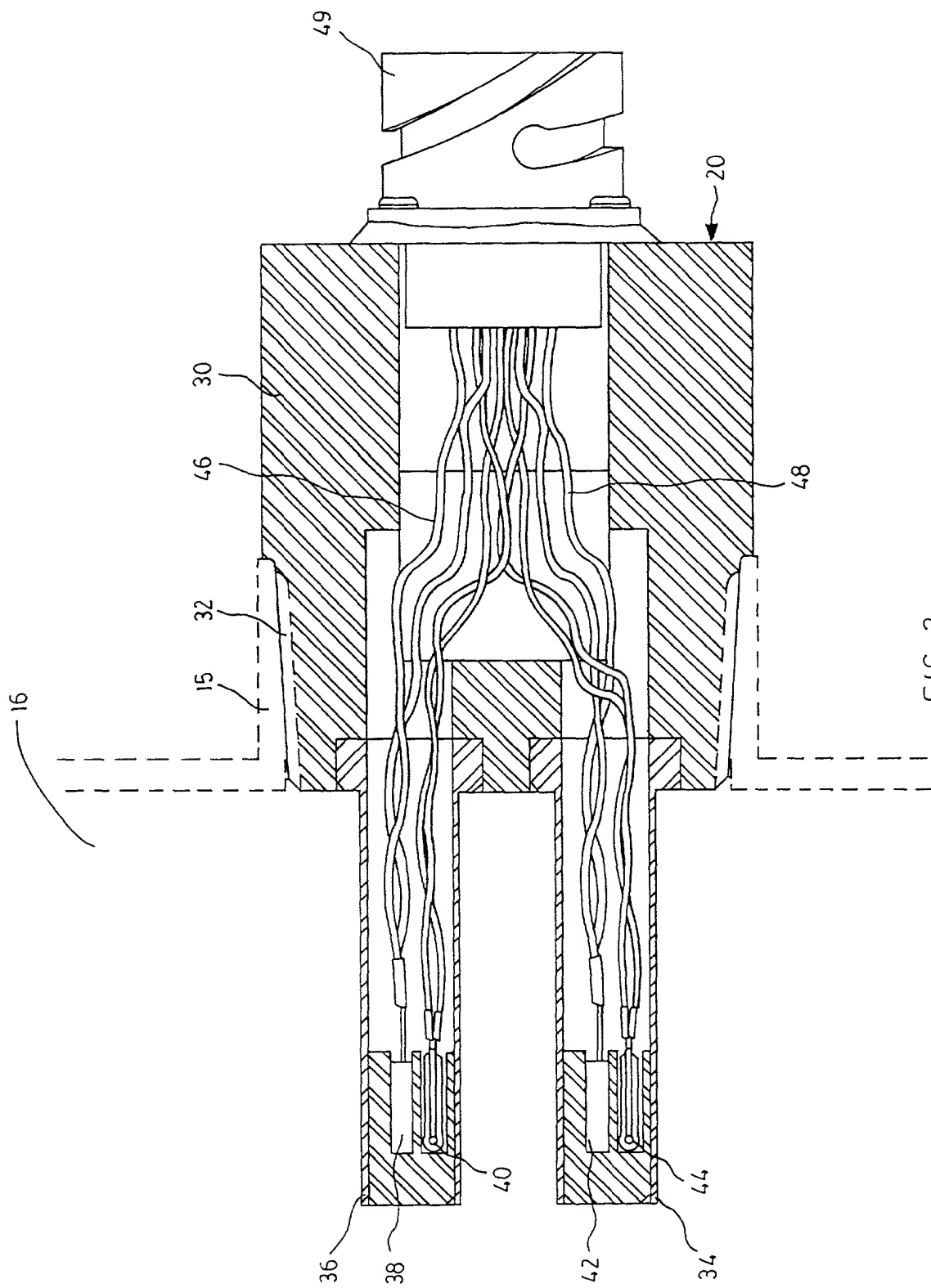


FIG. 2

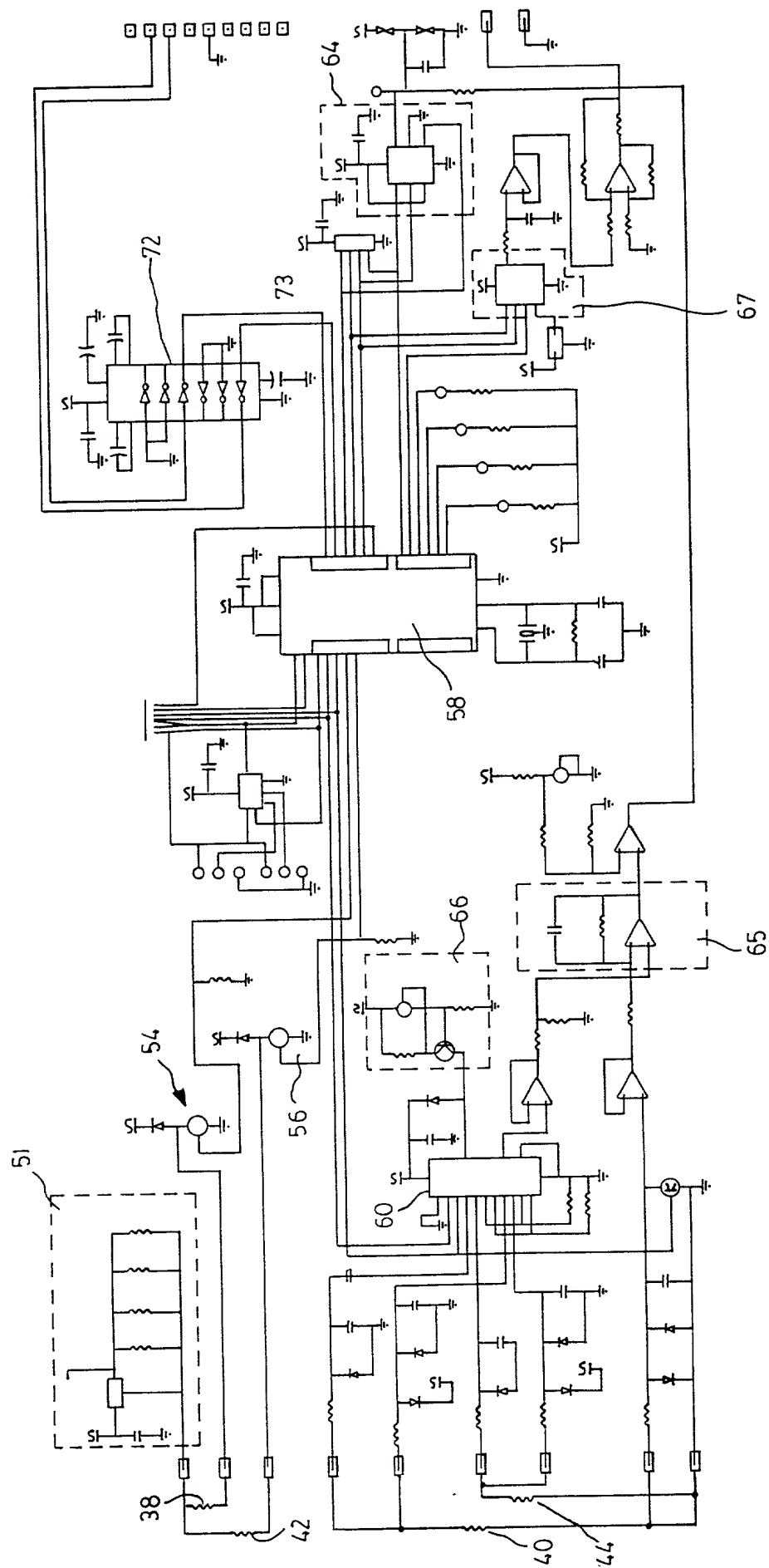


FIG. 5

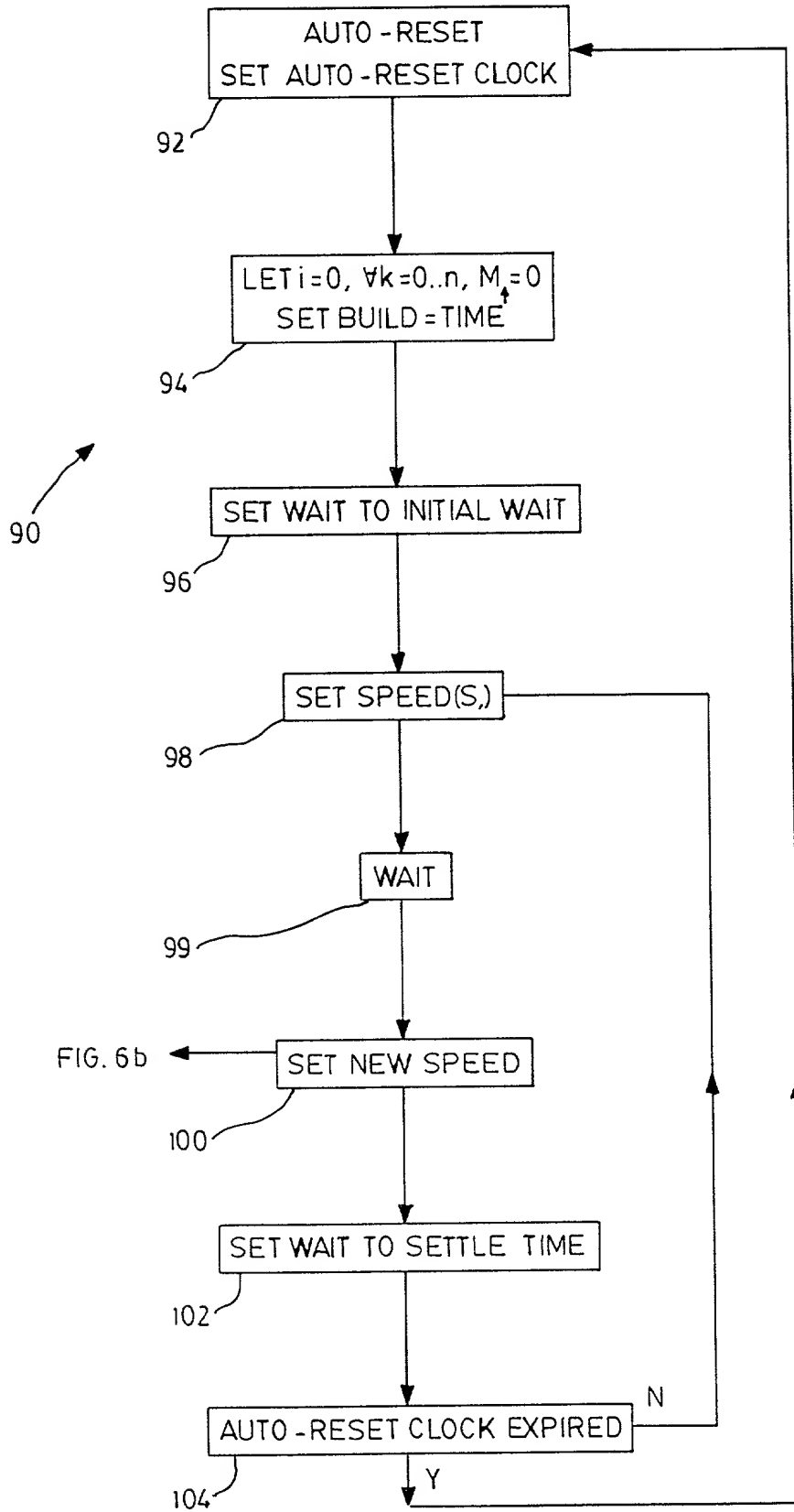


FIG. 6b

FIG. 6a

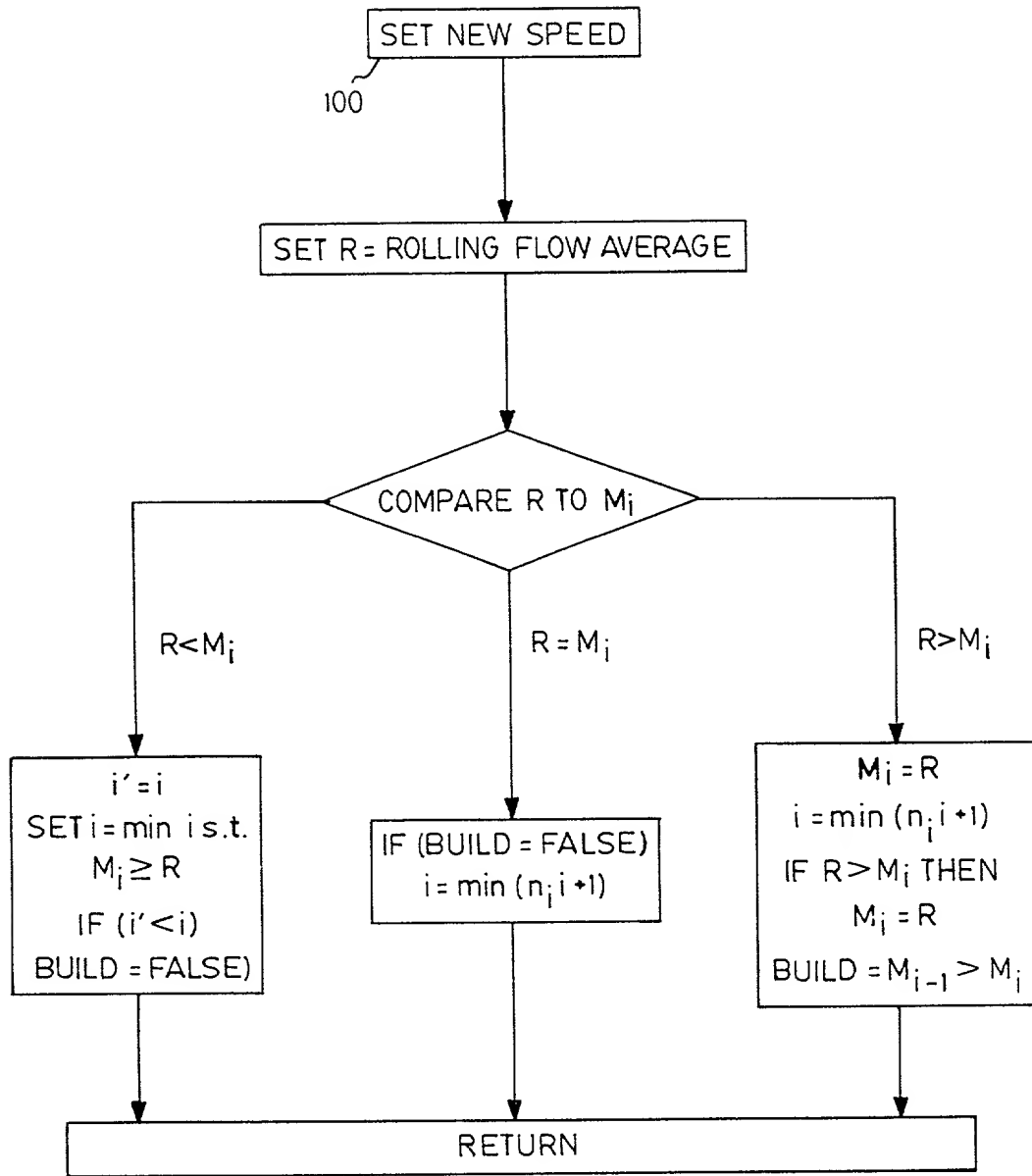


FIG. 6b

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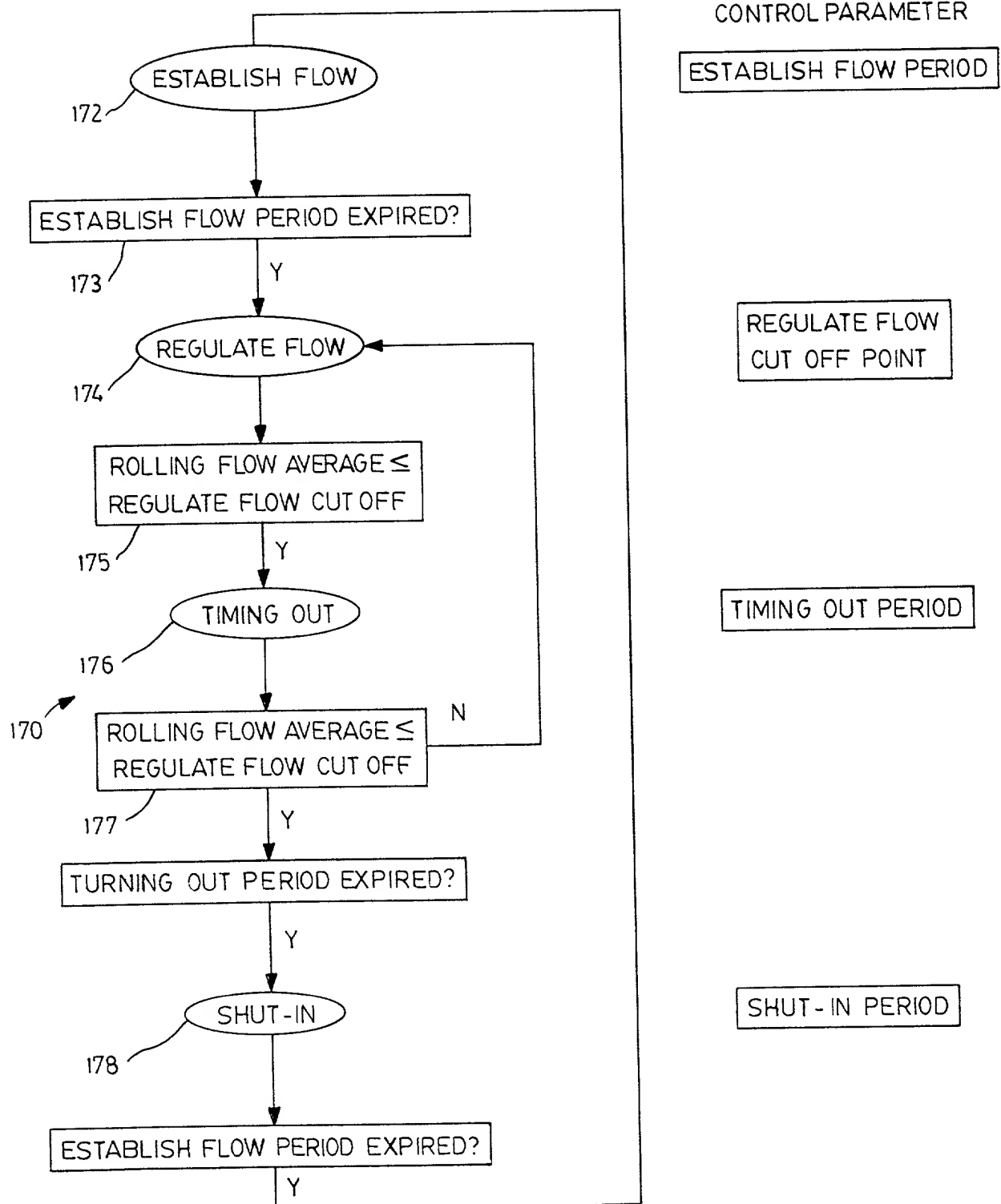


FIG. 7

Attorney's Docket No. 8700111-0002

PATENT

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL,
CONTINUATION OR C-I-P)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type:

(check one applicable item below)

- ☒ original.
- ☐ design.
- ☐ supplemental.

NOTE: If the declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application, do not check next item; check appropriate one of last three items.

- ☐ national stage of PCT.

NOTE: If one of the following 3 items apply, then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR C-I-P.

- ☐ divisional.
- ☐ continuation.
- ☐ continuation-in-part (C-I-P).

INVENTORSHIP IDENTIFICATION

WARNING: If the inventors are each not the inventors of all the claims, an explanation of the facts, including the ownership of all the claims at the time the first claimed invention was made, should be submitted.

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

oil well pump controller

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COFFIN IN BOX

(complete (a), (b) or (c))

NOTE: The following combinations of information supplied in an oath or declaration filed on the application filing date with a specification are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:

"[t]he name of inventor(s), and title which was on the specification as filed."

(b) ☐ was filed on _____, as ☐ Serial No. 0 / _____
or ☐ _____
and was amended on _____ (if applicable).

NOTE: The following combinations of information supplied in an oath or declaration filed after the filing date are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:

"(b) name of inventor(s), this which was on the specification as filed and accompanied by a cover letter accurately identifying the application for which it was intended by either the application number (consisting of the series code and the serial number; e.g., 08/123,456), or serial number and filing date. Absent any statement(s) to the contrary, it will be presumed that the application filed in the PTO is the application which the inventor(s) executed by signing the oath or declaration."

(c) ☐ was described and claimed in PCT International Application No. _____, filed on _____ and as amended under PCT Article 19 on _____ (if any).

Doc 67-2496 P. 64 (45)

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56,

(also check the following items, if desired)

- ☐ and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and
- ☐ in compliance with this duty, there is attached an information disclosure statement, in accordance with 37 CFR 1.98.

PRIORITY CLAIM (35 U.S.C. § 119(a)-(d))

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

(complete (d) or (e))

- (d) ☒ no such applications have been filed.
- (e) ☐ such applications have been filed as follows.

NOTE: Where item (c) is entered above and the international application which designated the U.S. itself claimed priority check item (e), enter the details below and make the priority claim.

**PRIOR FOREIGN/POT APPLICATION(S) FILED WITHIN 12 MONTHS
(6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION
AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)**

| COUNTRY (OR INDICATE IF POT) | APPLICATION NUMBER | DATE OF FILING (day, month, year) | PRIORITY CLAIMED UNDER 37 USC 119 |
|------------------------------------|--------------------|--------------------------------------|-------------------------------------------------------------|
| | | | <input type="checkbox"/> YES NO <input type="checkbox"/> |
| | | | <input type="checkbox"/> YES NO <input type="checkbox"/> |
| | | | <input type="checkbox"/> YES NO <input type="checkbox"/> |
| | | | <input type="checkbox"/> YES NO <input type="checkbox"/> |
| | | | <input type="checkbox"/> YES NO <input type="checkbox"/> |

**CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S)
(34 U.S.C. § 119(e))**

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATION NUMBER

FILING DATE

_____/_____/_____
_____/_____/_____
_____/_____/_____

**CLAIM FOR BENEFIT OF EARLIER US/POT APPLICATION(S)
UNDER 35 U.S.C. 120**

- ☐ The claim for the benefit of any such applications are set forth in the attached ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR CONTINUATION-IN-PART (C-I-P) APPLICATION.

(Declaration and Power of Attorney [1-1]—page 4 of 7)

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**ALL FOREIGN APPLICATION(S), IF ANY, FILED MORE THAN 12 MONTHS
(6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION**

NOTE: If the application filed more than 12 months from the filing date of this application is a PCT filing forming the basis for this application entering the United States as (1) the national stage, or (2) a continuation, divisional, or continuation-in-part, then also complete **ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR C-I-P APPLICATION** for benefit of the prior U.S. or PCT application(s) under 35 U.S.C. § 120.

POWER OF ATTORNEY

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

(list name and registration number)

John R.S. Orange

29, 275

(check the following item, if applicable)

- ☐ Attached, as part of this declaration and power of attorney, is the authorization of the above-named attorney(s) to accept and follow instructions from my representative(s).

SEND CORRESPONDENCE TO

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DIRECT TELEPHONE CALLS TO:
(Name and telephone number)

(416) 868-3457

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

(Declaration and Power of Attorney [1-1]—page 5 of 7)

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SIGNATURE(S)

NOTE: Carefully indicate the family (or last) name, as it should appear on the filing receipt and all other documents.

Full name of sole or first inventor

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(GIVEN NAME)

F.
(MIDDLE INITIAL OR NAME)

Bevan
(FAMILY OR LAST NAME)

Inventor's signature

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Post Office Address _____

Full name of second joint inventor, if any

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(MIDDLE INITIAL OR NAME)

Lownie
(FAMILY OR LAST NAME)

Inventor's signature

Date _____ Country of Citizenship Canada
Residence 19 King St., #1103, London, ON N6A 5N8, Canada

Post Office Address _____

Full name of third joint inventor, if any

(GIVEN NAME)

(MIDDLE INITIAL OR NAME)

(FAMILY OR LAST NAME)

Inventor's signature

Date _____ Country of Citizenship _____

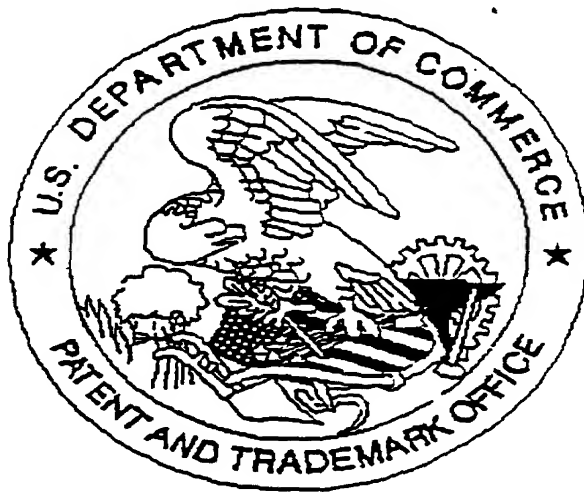
Residence _____

Post Office Address _____

(Declaration and Power of Attorney [1-1]—page 6 of 7)

05050760

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